E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(12): 38-43
Received: 21-10-2025
Accepted: 23-11-2025

Athul P
Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala, India

Bindhu JS
AICRP-Integrated Farming Systems Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, India

Shalini Pillai P
Department of Agronomy, College of Agriculture, Vellayani, Kerala Agricultural University, Thiruvananthapuram, Kerala, India

John J
AICRP -Integrated Farming Systems Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, India

Pratheesh, PG
Department of Agricultural Statistics, College of Agriculture, Vellayani, Kerala Agricultural University, Kerala, India

Corresponding Author:
Bindhu JS
AICRP-Integrated Farming Systems Research Station (IFSRS), Karamana, Thiruvananthapuram, Kerala, India

Agro-techniques for productivity enhancement in pulses under conservation agriculture: A comprehensive review

Athul P, Bindhu JS, Shalini Pillai P, John J and Pratheesh PG

DOI: https://www.doi.org/10.33545/2618060X.2025.v8.i12Sa.4331

Abstract
Pulses are the next most important food crop grown globally, providing nutritious food, feed, and fodder while conserving natural resources and maintaining ecological balance. Growing of pulses along with conservation tillage offers a promising path towards sustainable agriculture, enhancing soil health, increasing water retention and improving pulse yields while supporting environmental conservation and economic viability. By integrating practices like minimal soil disturbance, cover cropping, and precise nutrient management, farmers can reduce soil erosion and degradation, promote soil biota, and increase crop diversity. Conservation tillage helps sequester carbon, mitigate climate change, and reduce greenhouse gas emissions. Unhealthy practices like excessive tillage, burning crop residues, improper time and method of sowing crop and overusing of chemical fertilizers could contribute to declining soil health and resource degradation. Shifting to conservation tillage involving pulses with improved varieties of pulse crop offers farmers a more sustainable low cost option that can boosts productivity. Effective agro-techniques for pulses also involve crop rotation, organic amendments, and integrated pest management, leading to improved nutrient cycling, reduced chemical use, and enhanced ecosystem services. Pulses can make significant difference in conservation agriculture by enrichment of soil by nitrogen fixation, improves water holding capacity, and mitigate the need for harmful fertilizers. Minimum tillage can lead to major savings in fuel and labour. Overall, cultivation of pulses under conservation tillage represents a holistic approach to achieving agricultural sustainability, resource efficiency, and environmental stewardship, ultimately contributing to food security, rural development, and a more sustainable future.

Keywords: Climate change, conservation, pulses, soil health, sustainability

Introduction

Degradation of natural resources due to unscientific means of cultivation and changing climatic conditions are the major challenges facing today. According to the UN estimate, the global population will hit a milestone of 9.7 billion people by 2050. Under this scenario, global food demand will increase considerably from 59 to 98 per cent (FAO, 2022) [1]. To mitigate these issues and adapt to changing climatic conditions in a sustainable way, it is essential to diversify the cropping system. We require good agronomic practices and climate-resilient crops to triumph over the challenges. Pulses are the next most important food crop grown globally, providing nutritious food, feed, and fodder while conserving natural resources and maintaining ecological balance.

Grain legumes can be suitable for this purpose as they improve soil health and conserve resources (Kumar *et al*., 2018) [2]. Comparatively lower yield of pulses in India is attributed to several adverse factors such as abrupt climate changes, non-adoption of novel technologies and poor spread of improved cultivars. Pulses are the most popular and sustainable crop for the farmers of our country. Still we are unable to attain self -sufficiency and have to depend on foreign countries for our needs (Ahuja and Anantha, 2019) [3]. Cereal crops tend to drain large amount of nutrients without replenishing them and causes nutrient depletion which adversely affects soil quality. The addition of leguminous crop in the cropping system can helps restore soil fertility by its ability to naturally fix atmospheric nitrogen (Page *et al*., 2021) [4].

Tillage plays an important role in shaping the soils physical, biological and chemical conditions, causing an impact on the efficiency of nitrogen fixation (Kihara *et al*., 2012) [5]. The conservation tillage system is a method which is designed to preserve soil moisture in water stressed areas (Rana *et al.*, 2016) [6]. It helps to withstand biotic and abiotic stresses in pulses. The major objective of this tillage is to conserve soil and soil moisture. Conservation tillage is a farming approach that focuses on not disturbing the soil and keeping the crop residues on the field. Beyond increased yield, it also mitigate the release of harmful greenhouse gas from agriculture activities and fixes carbon from the atmosphere in the soil where it benefit plant growth. It also improves agricultural and environmental sustainability (Jat *et al*., 2021; Yuan *et al*., 2023) [7, 8].

Conservation agriculture had proved to be an excellent alternative to conventional agriculture by managing these crop residues effectively in the long term to achieve lasting, eco-friendly crop production, building up organic carbon in the soil for healthier, more resilient farming systems (Choudhury *et al*., 2014) [9]. Major source of short lived climate pollutants like methane and black carbon is burning of crop residues. Methane is a strong greenhouse gas which causes global warming, while air quality is affected by black carbon leading to health problems such as respiratory issues and making the air harder to see through (Sarkar *et al.*, 2018) [10]. Compared to the traditional tillage practices, using of minimum tillage can lead to major savings in fuel and labour. Several researchers have shown that minimum tillage can cut fuel use for land preparation by 60 to 66 per cent and reduce labour needs by 70 to 74 percent (Dev *et al.*, 2023) [11]. This review examines various agro-techniques in pulses under conservation tillage and its role in promoting sustainable agriculture by identifying current evidences and discusses strategies for enhancing productivity, soil health and environmental sustainability.

The various agro techniques for pulses under conservation tillage are reviewed below**.**

Soil Management

1. Tillage and Seed bed Preparation

Tillage plays an important role in shaping the soils physical, biological and chemical conditions, causing an impact on the efficiency of nitrogen fixation (Kihara *et al*., 2012) [5]. The conservation tillage system is a method which is designed to preserve soil moisture in water stressed areas (Rana *et al.*, 2016) [6]. It helps to withstand biotic and abiotic stresses in pulses. Zero tillage is a type of conservation tillage where the soil is left undisturbed and keeping crop residues on soil surface. Kumar *et al.* (2012) conducted a study at IIPR, Kanpur in chickpea and expressed yield advantage of conservation tillage in the rice-chickpea system over conventional tillage. The chickpea yield were noticeably higher when crop is sown using zero tillage (ZT) drill and ZT dibbling methods along with surface retention of crop residues after the rice harvest under rainfed conditions. This approach leads to an increased productivity of up to 28.2 per cent compared to traditional tillage practices [12]. Banjara *et al.* (2017) done a field experiment to explore the impact of various tillage methods in the growth and yield of chickpea when plant after harvesting rice. Out of the four different treatment tested, the study revealed significant differences in chickpea yield, with high yield in the minimum tillage with line sowing three days after rice harvest [13].

Abid *et al.* (2018) evaluated how different green gram varieties responded to various tillage practices and found that minimum tillage combined with herbicide spray of imazethapyr and imazamox combination at 80 g ha^{-1} applied 20 days after sowing led to superior yield attributes, which was comparable to conventional tillage followed by two hand weedings[14].

Conservation tillage practices ranging from zero-till drill sowing to minimum tillage with line sowing or using post emergent selective herbicides consistently provides yield equal or higher than conventional tillage practices in pulses. Beyond yield, it effects in sustainable pulse production causing long term soil health, residue management and improved resource use efficiency.

2. Land Configuration

The raised bed planting system has been found effective for pulses, reducing costs and increasing productivity by minimizing tillage and preserving water. In a maize-based cropping system in eastern Himalayas, Yadav *et al.* (2021) studied six different combinations of tillage and planting methods under conservation tillage. The results showed that no-till raised bed planting was the most effective, improving soil properties, carbon sequestration, and boosted field pea seed yield after maize, making the entire system more sustainable for similar agro-ecological regions [15]. These highlight its potential as an effective climate resilient strategy for farmers in water scarce and soil degraded lands.

3. Microbial Inoculants

Microbial inoculants offer a cost effective, low-investment, non-bulky and environmental friendly alternative to synthetic fertilizers. They are renewable and help in the mobilization of nutrients in the soil to improve plant nutrition, consequently boosting the farm productivity in a sustainable way (Jaga and Sharma, 2015) [16]. Bhardwaj *et al.* (2024) conducted a study comparing two tillage method of conventional tillage (CT), zero tillage (ZT) alongside eight different combination of biofertilizer inoculation of *Rhizobium* sp., phosphorus solubilizing bacteria (PSB) and vesicular arbuscular mycorrhizae (VAM). The results indicated that zero tillage combined with biofertilzer treatments significantly improved soil health due to the increment in organic carbon, available nitrogen and phosphorus levels. Plants grown under these treatment also have a higher number of nodules, along with higher fresh and dry nodules weight. Furthermore, the seed treatments influenced the levels of DTPA-extractable iron and manganese in the soil supporting better nutrient availability [17]. Integrating microbial inoculants along with zero tillage mitigate reliance on chemical fertilizers enhances nutrient cycling and soil fertility making it a cost effective and sustainable strategy for long term benefits.

Crop Management

1. Sowing Window

Singh *et al.* (2017) reported that in rice along with pulse relay cropping system in Southern India, broadcast of black gram seeds at 4 to 6 days before rice harvest with life-saving irrigation showed better result compared to other treatments [18]. Productivity can be increased by using higher-yielding varieties proper time of planting by adopting suitable establishment techniques in pulses. The time of sowing depends on the receipt of rainfall, cropping system, and variety (DPD, 2020) [19]. Timely sowing and adoption of improved establishment practices like relay cropping with pulses can substantially increase pulse yields under varying rainfall and cropping system conditions.

2. Improved Genotypes

The quality and yield of mung bean can be improved significantly by following compatible agronomic practices and choosing high yielding varieties. Different cultivars can vary in their yield and yield traits (Ayub *et al*., 1999) [20]. The rice based fallow system offers great potential to expand winter pulse cultivation area by using fast growing varieties in post monsoon soil (Kumar *et al*., 2018) [2]. An early maturity, faster attainment of phenophases, early ground cover posing characteristics is considered as advisable plant characters for water stressed rice-fallow systems (Bandyopadhyay *et al*., 2016) [21]. The study conducted by Sandhu and Makkar (2024) identified SML-832 as the best pulse variety of green gram due to its higher yield, early maturity, better profitability, and soil-enriching ability. With proper practices like seed priming, biofertilizer use, and IPM, it boosted net returns and showed strong resistance to pests and weeds, making it ideal for sustainable farming in Punjab's sub-mountainous regions [22].

Comprehensive evaluation conducted by Tamilselvan *et al.* (2025) observed blackgram variety VBN11 showed exceptional drought tolerance and leaf greenness even at 38 percent soil moisture, making it ideal for rainfed and drought-prone regions. In addition chickpea variety JG16 also demonstrated excellent resilience under water stress, maintaining photosynthetic activity longer than other genotypes. CO8 variety emerged as the most tolerant green gram variety, sustaining high canopy health and chlorophyll fluorescence even under severe drought [23]. High yielding, stress tolerant pulse genotypes have shown significant improvements in yield and resilience when combined with suitable agronomic practices making them suitable for sustainable and water stressed ecosystems.

3. Nutrient Management

Fertilizers are crucial for crop production and productivity. However, continuous and imbalanced use of chemical fertilizers can degrade soil health. Pulses can fulfil 80-90 percent of nitrogen needs through biological nitrogen (N) fixation, needing only a supplement of 15-25 kg N ha^{-1}. Recent practices include the application of 20-30 kg ha^{-1} of sulphur and essential micronutrients has found beneficial. Additionally band placement of phosphorus fertilizers along with bio-fertilizers has shown to boost the efficiency of both added and naturally present phosphorus in the soil (Arora and Bhan, 2017) [24]. Studies conducted by Datta *et al*. (2025) found that ten years of Integrated nutrient management enhanced microbial growth and boosted soil productivity, leading to sustainable crop yields [25].

The integration of pulses into cropping system not only enhances nutrient availability in the soil but also causes desirable changes to its physical and biological properties, consequently boosting the overall soil fertility (Kumar *et al.*, 2018) [2]. But in continuous use of conventional tillage adversely impact the soil causing soil compaction, loss of organic matter, breakdown of soil structure, reduced amount of carbon bound in the soil in the form of humus and depletion of beneficial soil microorganisms (Kar *et al*., 2021) [26]. In an investigation done by Nthebere *et al.* (2025) has found that reduced tillage retaining crop residues done under conservation agriculture significantly improved soil organic carbon (SOC) levels, enhanced availability of soil nutrients specifically nitrogen (N) and phosphorus (P), consequently contributed to healthier and more fertile soils over times [27].

Zero-till planting can result in significant savings in soil nutrients and water (up to 20-30 percent), especially for crops that are bed-planted and laser-leveled (Bhan *et al*., 2014) [28]. Incorporation of the pigeon pea imparts 2.5 to 5.0 kg of phosphorus and 13.5 to 24.0 kg of potassium per hectare through its leaf litter during the growing season enriching the soil with key nutrients growth (Nadarajan *et al*, 2018) [29]. Integrating pulses and conservation practices such as reduced tillage, residue retention and green manuring reverse the negative impact of continuous conventional tillage. These strategies conserves soil and water boosts yield of subsequent crop in rotation due to increased phosphorous and potassium inputs from legume residues.

4. Irrigation Management

Pulses having higher water use efficiency is a suitable crop grown under moisture stressed environments (Siddique *et al.*, 2008) [30]. Pulses thrive better when grown along with irrigation, because irrigation water plays a crucial factor in boosting their productivity. The amount of irrigation water required by pulses can vary widely from barely as 5.7 mm during rainy season to as much as 609 mm in dry conditions. As a result, the average water productivity of major pulse spans from 0.67 to 7.51 kg per hectare, depending on the crop and growing environment (Ray *et al.*, 2023) [31].

In a study carried out by DeVita *et al.* (2007) observed decreased evaporation in no tillage systems, as the soil was less disturbed and better protected by surface residues consistently maintaining about 20 percent more soil moisture level compared in contrast to traditional tillage methods. Conservation tillage enhances the infiltration of water by maintaining structure of the soil and reducing surface runoff. The presence of macropores, formed by earthworms and plant roots, facilitates the descending movement of water entering the soil profile and it ensures adequate water storage in the root zone [32]. In addition, conservation tillage tends to mitigate soil erosion caused due to heavy rainfall. The residue cover above the surface of the soil dissipates kinetic energy of raindrops, preventing the breakdown and movement of soil particles. This not only preserves the soil's physical integrity but also minimizes nutrient losses associated with erosion (Lv *et al.*, 2023) [33].

Ali *et al.* (2014) advocated no disturbance in the soil and withholding of approximately 20 to 25 per cent of crop residue on the soil surface as the two basic principles of resource conservation technology (RCT) [34]. Hedayetullah and Sadhukhan (2018) found that, the broadcasting of chickpea seed in standing rice before 15 days of its harvest (relay crop) resulted in higher yield (1.44 and 1.41 t ha^{-1}) for two consecutive years [35]. Under zero tillage, the soil moisture content was almost 20 percent higher as compared to traditional tillage throughout the course of growing seasons (Boruah *et al.*, 2024) [36]. In summary irrigation optimization under conservation tillage improves water productivity, reduces evaporation losses and improves infiltration through better soil structure.

Weed Management

Weed infestation in pulse crops varies based on agro-ecological conditions and cultural practices, with different types of weeds affecting growth and yield (Kumar *et al.*, 2016) [37]. Conservation agriculture practices, such as crop residue retention and intercropping, help suppress weed growth and improve crop yield by increasing shade and crop competitiveness (Singh *et al.*, 2014) [38]. Nichols *et al.* (2015) evaluating various studies concluded that no tillage causes accumulation of weed seed bank on the top surface which makes it prone to predation, that renders it difficult to penetrate into deeper layers [39]. Abid *et al.* (2018) reported that the mungbean variety Co 8 cultivated under under minimum tillage along with a post emergence application of herbicide mix imazethapyr + imazamox at 80 g ha^{-1} applied 20 days after sowing showed promising results in terms of yield and profitability making it suitable for summer rice fallow [14]. Singh *et al*. (2023) evaluated the weed management practices for summer mungbean under zero tillage condition. Their findings revealed that weed free plots recorded the best growth, followed by units treated with post emergence application of herbicide combination (Propaquizafop + Imazethypyr) at 20 DAS and Pendimethalin as pre-emergence herbicide followed by one hand weeding at 20 DAS [40].

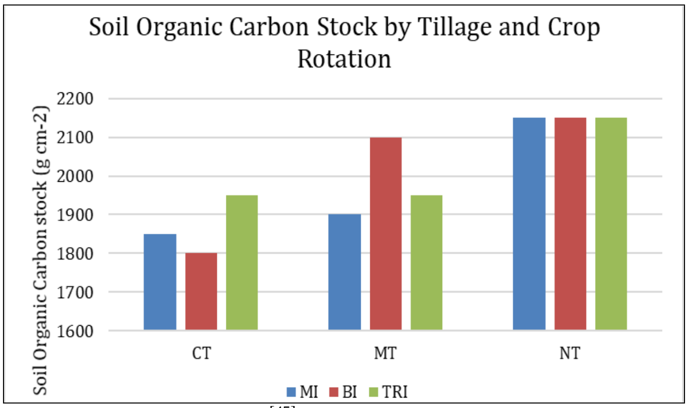
Surface seeding with mulching offers an eco-friendly method for managing crop residues, conserving water, reducing herbicide use, and protecting crops from heat stress, while eliminating the harmful practice of paddy straw burning. Utilizing aquatic weeds as mulch along with zero tillage in rice-based systems aids in recycling bio-resources, enhancing soil fertility, and improving soil quality and resource use efficiency (Dey *et al*., 2023) [41]. Importantly, no till accumulates weed seeds on the soil surface exposing it to weathering and predation, potentially declines the the seed bank over time.

Cropping System Approach

Crop diversification is an important practices in conservation agriculture involves sowing various crops alternatively in the same piece of land in sequence year after year. Diversified system can optimize the productivity by making the cropping system more resilient to biotic and abiotic stress. Even a crop suffers yield loss, farmers can still earn profit from succeeding crop (Singh *et al*., 2022) [42]. Rotating crops alters the condition that favour certain weeds, preventing one weed from being repeatedly successful, and making it harder to dominate preventing its establishment (Nichols *et al*., 2015) [39]. Kumar *et al*. (2023) comprehensively examined the effect of integrating pulses based cropping system in rainfed farming. This system can rejuvenate soil health and can restore degraded lands [43].

Nath *et al*. (2023) demonstrated that integrating pulse crops and organic amendments into cereal-based cropping systems significantly improved soil physical, chemical, and biological properties, enhancing long-term soil health and crop productivity. Systems like pigeonpea-wheat (P-W) and maize-wheat-mungbean (M-W-Mb) with integrated nutrient management (INM) were effective strategies for sustainable agricultural intensification in the Indo-Gangetic Plains [44].

Jaziri *et al*. (2022) examined the lasting consequences of tillage and crop rotation influence soil organic carbon levels and microbial activity in a wheat-based system within the semi-arid Mediterranean region. The study showed that no-till practices improved organic carbon stock. It also found that crop diversification had a positive impact on soil microbial activity (Fig.1) [45].



(Source: Jaziri *et al*., *2022)* [45]

Fig 1: Effect of tillage and crop rotation on the soil organic carbon stock

Alekhya *et al*. (2024) suggested integrating pulses as a solution to restore the degraded land in Indo Gangetic plains caused due to repetitive and intensive cultivation of rice and wheat, particularly combining with conservation agriculture methods minimising soil disturbances and maintaining soil cover to significantly enhance both soil health and productivity. Emphasized the superiority of multiple pulse based cropping patterns over conventional systems in terms of yield and profit [46]. Additionally contributing to climate resilient and long term sustainable agriculture by mitigating greenhouse gas emissions and nutrient leaching.

Arya *et al*. (2024) reviewed that pulses can make significant difference in conservation agriculture by enrichment of soil by nitrogen fixation, improves water holding capacity, and mitigate the need for harmful fertilizers. They thrive in tough conditions, making them suitable for dry and degraded lands. In addition to the increment in productivity of the staples by crop rotation or intercropping with pulses, it also promote cutting greenhouse gases and suppress weed growth [47]. Dutta *et al*. (2024) reported that crop diversification using chickpea with integrated nutrient management can boost the phosphorous availability and productivity [48].

Conclusion

Pulses being a nutrient rich, climate resilient crop nourishing the soil by nitrogen fixation, increasing organic carbon pool, boosting microbial activity and improving water retention and soil structure which plays a transformative role in enhancing agricultural sustainability across diverse systems. Conservation agriculture, when paired with diversified cropping systems with pulses reduces environmental footprints through maximum resource use efficiency along with building of resilience against climate stress. Further long-term studies and on-farm trials are needed to line- tune these practices for different regions and pulse crops. Understanding nutrient, weed, disease and insect pest dynamics in conservation tillage system of pulses and breeding specifically suited to conservation tillage systems will help in scaling up conservation agriculture with pulses.

Soil management practices such as zero tillage and residue retention improve soil structure, conserve moisture, and reduce input costs. Crop management methods, including improved genotypes, balanced nutrient application, and efficient irrigation, further boost resilience and productivity. Cropping system approaches, such as cereal-pulse rotations and intercropping, provide long-term benefits for soil nitrogen and overall system sustainability. These strategies provide higher yields and profitability along with reduced dependence on chemical fertilizers and attributes to resilience against climatic stress. However, long-term multi-location studies are required to refine conservation practices for diverse agro-ecological regions. Further research should address pest and weed dynamics in zero-till pulses and develop varieties specifically suited for conservation agriculture. Addressing these gaps will be crucial for scaling adoption and realizing the full potential of pulses under conservation.

References

1. Food and Agriculture Organization of the United Nations. Emerging trends and sustainability challenges in the global agri-food system. Rome: FAO; 2022. https://www.fao.org/home/en
2. Kumar N, Hazra KK, Nath CP, Praharaj CS, Singh U. Grain legumes for resource conservation and agricultural sustainability in South Asia. In: Legumes for Soil Health

and Sustainable Management. 2018. p. 77-107.
3. Ahuja R, Anantha KH. Enhancing and sustaining pulse production and farmer incomes in the TRFA States: Issues of stray animal grazing and value chain integration for small and marginal farmers. New Delhi: Food and Agriculture Organization of the United Nations, India; 2019. p. 84.
4. Page KL, Dang YP, Martinez C, Dalal RC, Wehr JB, Kopittke PM. Review of crop-specific tolerance limits to acidity, salinity, and sodicity for seventeen cereal, pulse, and oilseed crops common to rainfed subtropical cropping systems. Land Degrad Dev. 2021;32(8):2459-2480.
5. Kihara J, Bationo A, Waswa B, Kimetu JM, Vanlauwe B, Okeyo J. Effect of reduced tillage and mineral fertilizer application on maize and soybean productivity. Exp Agric. 2012;48(2):159-175.
6. Rana DS, Dass A, Rajanna GA, Kaur R. Biotic and abiotic stress management in pulses. Indian J Agron. 2016;61:238-248.
7. Jat HS, Datta A, Choudhary M, Sharma PC, Jat ML. Conservation agriculture: factors and drivers of adoption and scalable innovative practices in Indo-Gangetic plains of India - a review. Int J Agric Sustain. 2021;19(1):40-55.
8. Yuan J, Sadiq M, Rahim N, Tahir MM, Liang Y, Zhuo M, *et al*. Changes in soil properties and crop yield under sustainable conservation tillage systems in spring wheat agroecosystems. Land. 2023;12(6):1253.
9. Choudhury SG, Srivastava S, Singh R, Chaudhari SK, Sharma DK, Singh SK, *et al*. Tillage and residue management effects on soil aggregation, organic carbon dynamics and yield attribute in rice-wheat cropping system under reclaimed sodic soil. Soil Tillage Res. 2014;136:76-83.
10. Sarkar S, Singh RP, Chauhan A. Crop residue burning in northern India: increasing threat to greater India. J Geophys Res Atmos. 2018;123(13):6920-6934.
11. Dev P, Khandelwal S, Yadav SC, Arya V, Mali HR, Yadav KK. Conservation agriculture for sustainable agriculture. Int J Plant Soil Sci. 2023;35(1).
12. Kumar N, Singh MK, Ghosh PK, Venkatesh MS, Hazra KK, Nadarajan N. Resource conservation technology in pulse based cropping systems. Kanpur: Indian Institute of Pulses Research; 2012. p. 249-251.
13. Banjara TR, Pali GP, Tigga BK, Kumar S, Shori A. Effect of different tillage practices on growth, yield and economics of chickpea (*Cicer arietinum* L.) under rainfed condition of Chhattisgarh. Int J Curr Microbiol Appl Sci. 2017;6(2):1464-1470.
14. Abid V, Bindhu JS, Prameela P, Thomas CG. Performance of greengram, *Vigna radiata* (L.) Wilczek cultivars under different tillage methods. J Crop Weed. 2018;14(3):178-184.
15. Yadav GS, Das A, Babu S, Mohapatra KP, Lal R, Rajkhowa D. Potential of conservation tillage and altered land configuration to improve soil properties, carbon sequestration and productivity of maize-based cropping system in eastern Himalayas, India. Int Soil Water Conserv Res. 2021;9(2):279-290.
16. Jaga PK, Sharma S. Effect of bio-fertilizer and fertilizers on productivity of soybean. Ann Plant Soil Res. 2015;17(2):171-174.
17. Bhardwaj S, Sutaliya JM, Parkash R, Bhardwaj KK, Kumar N, Ahlawat I, *et al*. Zero tillage in combination with seed treatment by different biofertilizers increased soil organic carbon, macro and micronutrients status and nodulation under faba bean (*Vicia faba* L.). Legume Res. 2024;47(7):1203-1207.
18. Singh SS, Kumar N, Praharaj CS, Singh NP. Agrotechnologies for enhancing pulses production in rice fallows. Kanpur (UP): ICAR-Indian Institute of Pulses Research; 2017. 36 p.
19. Directorate of Pulses Development. Ready reckoner of pulses. Bhopal: DPD; 2020. https://www.dpd.gov.in
20. Ayub M, Tanveer A, Choudhry MA, Amin MMZ, Murtaza G. Growth and yield response of mungbean (*Vigna radiata* L.) cultivars to varying levels of nitrogen. Pak J Biol Sci. 1999;2(4):1378-1380.
21. Bandyopadhyay PK, Singh KC, Mondal K, Nath R, Ghosh PK, Kumar N. Effects of stubble length of rice in mitigating soil moisture stress and on yield of lentil (*Lens culinaris* Medik) in rice-lentil relay crop. Agric Water Manag. 2016;173:91-102.
22. Sandhu O, Makkar G. Impact assessment of cluster front line demonstrations on summer moong (*Vigna radiata* L.) in sub-mountainous region of Punjab, India. Agric Res J. 2024;10(6).
23. Tamilselvan A, Kumar M, Krishnaveni A, Rane J. Evaluation of drought tolerance in pulses by assessing PS-II efficiency and leaf greenness under moisture deficit stress. Plant Arch. 2025;25(1):251-256.
24. Arora S, Bhan S. Sustainable farming and soil health management. New Delhi: Soil Conservation Society of India; 2017. 374 p.
25. Datta S, Mazumdar SP, Majumdar B, Alam NM, Chattopadhyay L, Ghosh S. Impact of integrated nutrient management on soil microbiome diversity and health in rice-based cropping system: insights from long-term agricultural practices. Rhizosphere. 2025;33:101048.
26. Kar S, Pramanick B, Brahmachari K, Saha G, Mahapatra BS, Saha A. Exploring the best tillage option in rice based diversified cropping systems in alluvial soil of Eastern India. Soil Tillage Res. 2021;205:104761.
27. Nthebere K, Tata RP, Gudapati J, Bhimireddy P, Admala M, Chandran LP. Assessment of conservation agriculture on soil nutrient's stratification ratio, carbon sequestration rate, management indices and crop productivity in Southern Telangana India. Sci Rep. 2025;15(1):15038.
28. Bhan S, Behera UK. Conservation agriculture in India: problems, prospects and policy issues. Int Soil Water Conserv Res. 2014;2(4):1-12.
29. Nadarajan N, Kumar N, Singh VK, Gangwar B. Role of pulses in conservation agriculture. In: System Based Conservation Agriculture. New Delhi: Westville Publishing House; 2018. p. 134-154.
30. Siddique I, Engel VL, Parrotta JA, Lamb D, Nardoto GB, Ometto JP. Dominance of legume trees alters nutrient relations in mixed species forest restoration plantings within seven years. Biogeochemistry. 2008;88(1):89-101.
31. Ray LI, Swetha K, Singh AK, Singh NJ. Water productivity of major pulses: a review. Agric Water Manag. 2023;281:108249.
32. De Vita P, Di Paolo E, Fecondo G, Di Fonzo N, Pisante M. No-tillage and conventional tillage effects on durum wheat yield, grain quality and soil moisture content in southern Italy. Soil Tillage Res. 2007;92(1-2):69-78.
33. Lv L, Gao Z, Liao K, Zhu Q, Zhu J. Impact of conservation tillage on the distribution of soil nutrients with depth. Soil Tillage Res. 2023;225:105527.
34. Ali M, Ghosh PK, Hazra KK. Resource conservation

technologies in rice fallow. In: Resource Conservation Technology in Pulses. 2014. p. 83-88.
35. Hedayetullah M, Sadhukhan R. Production technology of relay chickpea under rice fallow for sustainable agriculture. J Agroecol Nat Resour Manage. 2018;5(2):122-124.
36. Boruah A, Kumar M, Sonia H. Prospects and issues in the adoption of conservation agriculture in India. Int J Environ Clim Change. 2024;14(9):279-287.
37. Kumar N, Nath CP, Hazra KK, Sharma AR. Efficient weed management in pulses for higher productivity and profitability. Indian J Agron. 2016;61(4):519-523.
38. Singh VP, Barman KK, Singh R, Sharma AR. Weed management in conservation agriculture systems. Jabalpur: ICAR-Directorate of Weed Research; 2014. 60 p.
39. Nichols V, Verhulst N, Cox R, Govaerts B. Weed dynamics and conservation agriculture principles: a review. Field Crops Res. 2015;183:56-68.
40. Singh G, Iqbal T, Paswal S, Sharma LK. Identification of different pulse crops grown and inputs used for their cultivation in temperate area of Jammu region. Agric Mech Asia. 2023;54(4):12663-12672.
41. Dey JK, Saren BK, Duary B, Pramanik K. Performance of zero-till bio-mulching on different pulses under maize-legume sequence. Legume Res. 2023;46(2):176-180.
42. Singh D, Dhiman SK, Kumar V, Babu R, Shree K, Priyadarshani A. Crop residue burning and its relationship between health, agriculture value addition, and regional finance. Atmosphere. 2022;13(9):1405.
43. Kumar S, Gopinath KA, Sheoran S, Meena RS, Srinivasarao C, Bedwal S. Pulse-based cropping systems for soil health restoration, resources conservation, and nutritional and environmental security in rainfed agroecosystems. Front Microbiol. 2023;13:1041124.
44. Nath CP, Dutta A, Hazra KK, Praharaj CS, Kumar N, Singh SS. Long-term impact of pulses and organic amendments inclusion in cropping system on soil physical and chemical properties. Sci Rep. 2023;13(1):6508.
45. Jaziri S, M’hamed HC, Rezgui M, Labidi S, Souissi A, Rezgui M. Long term effects of tillage-crop rotation interaction on soil organic carbon pools and microbial activity on wheat-based system in Mediterranean semi-arid region. Agronomy. 2022;12(4):953.
46. Alekhya G, Darjee S, Rajareddy G, Reddy KS, Kumar A, Reddy AJ. Integrating pulses into conservation agriculture for sustainable soil health and productivity in the Indo-Gangetic Plains. J Sci Res Rep. 2024;30(9):560-570.
47. Arya AP, Pi PY, Raj SK, Pillai S. Pulses as a key component in conservation agriculture: impacts on soil health and sustainability. Int J Plant Soil Sci. 2024;36(11):159-172.
48. Dutta A, Hazra KK, Nath CP, Kumar N, Singh SS, Praharaj CS. Long-term impact of legume-inclusive diversification and nutrient management practices on phosphorus dynamics in alkaline Fluvisol. Sci Rep. 2024;14(1):65.